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UWBG ULTRAWIDE BANDGAP POWER ELECTRONICS

Size Dictated Thermal Conductivity of GaN

Identifying the Dominant Scattering Source in Device Layers

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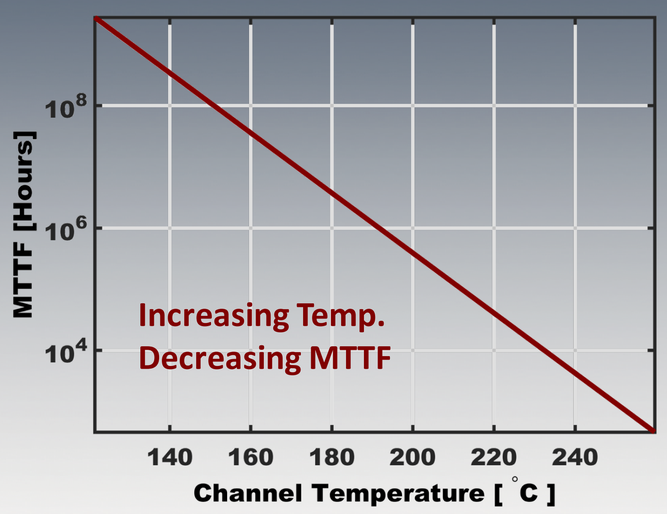
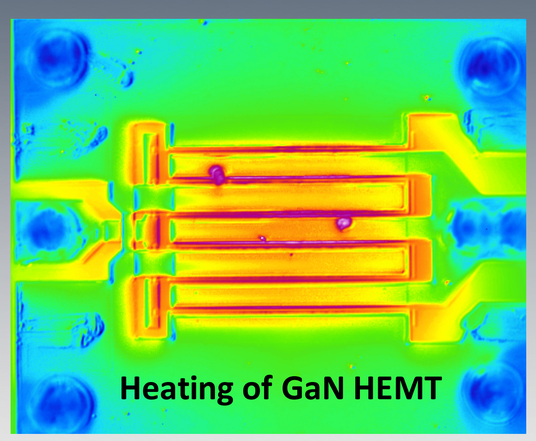
Problem: Performance and reliability of GaN devices decreases with increased operating temperature.

Belief: Thermal conductivity of GaN is high, >230 W/mK

Premise: Device fabrication lessens thermal conductivity. How much? Why?





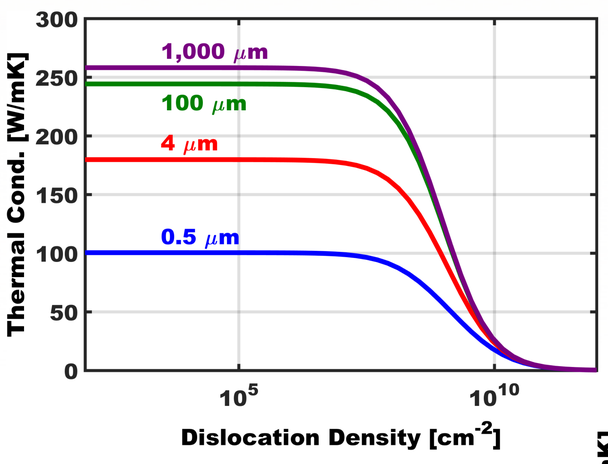
Adapted from Yamaki et al. SEI Tech. Rev. (76) 69 2013 .

What limits thermal conductivity in devices?

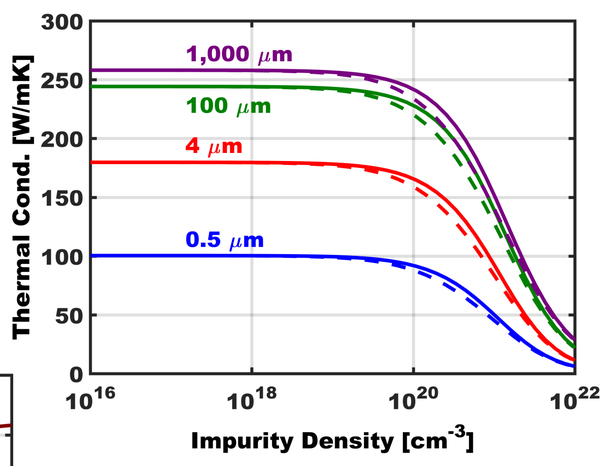
Scattering Sources

Phonon scattering caused by **dislocations**, **dopants**, or the **size** (i.e., thickness) of the layer.

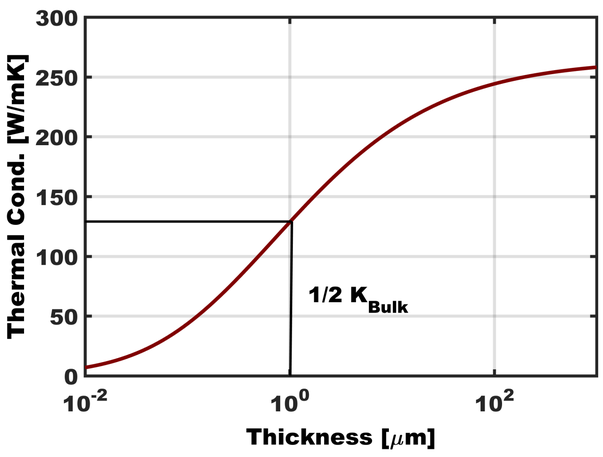
Approach: Estimate when each effect dominates.



Dislocations degrade transport at >10^8 cm^{-2}. Less impactful as layer thickness decreases.



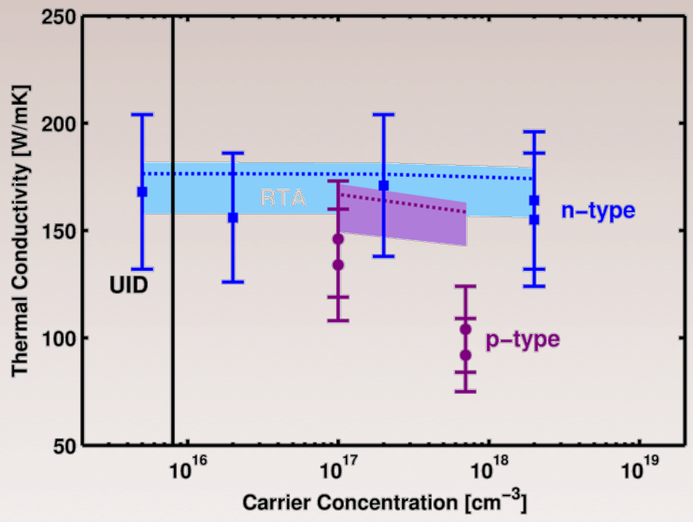
Impurities (i.e., dopants) lessen conductivity at concentrations >10^{18} cm^{-3}



Size impacts at scale of device

Size Effects

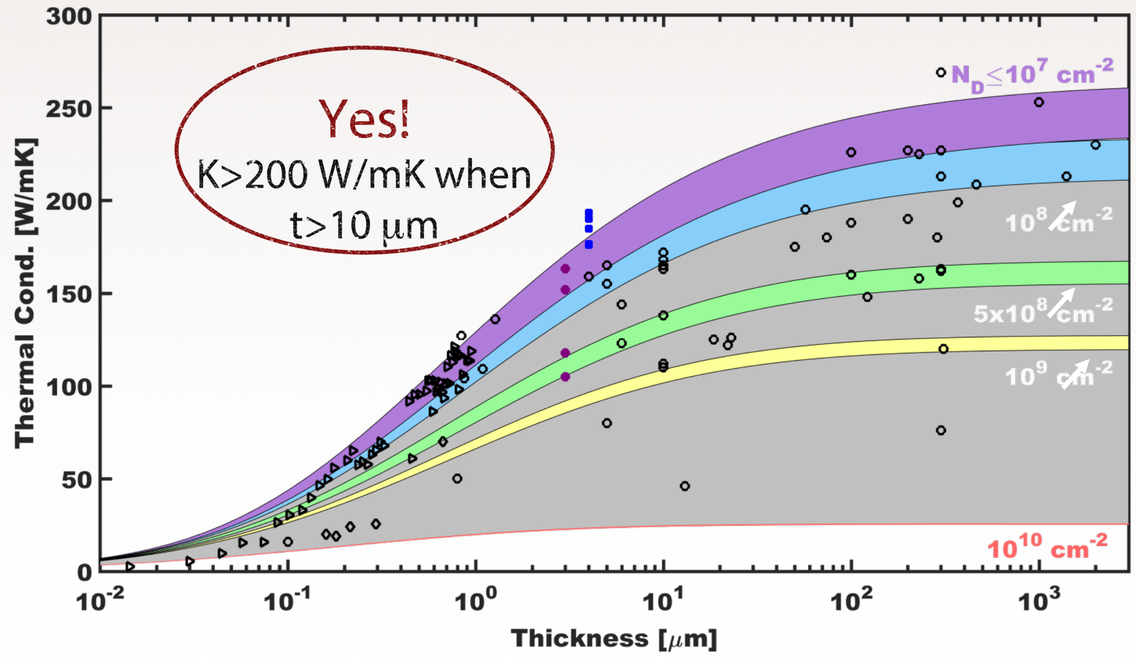
Observation: Thermal conductivity unaffected by n-type doping but decreases with p-type. Use phonon scattering models to interpret.



p-type degrades owing to presence of hydrogen (impurity dominated).

n-type constant owing to layer thickness (4 μm).

Does layer thickness dictate even when >1μm?



Device layers are typically <20 μm. Thermal conductivity will be less than "textbook" even if "perfect" owing to size effects.

Takeaways

Heat & Power Electronics

Big voltages and currents mean big heating. Removing heat necessary to realize performance and reliability gains.

Device Layers & Thermal Transport

Fabrication of device layers—doping, thickness etc.—can lessen thermal conductivity from "textbook" value.

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Size dictated thermal conductivity of GaN

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GaN devices: Size dictates thermal conductivity

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